eRD101 - mRICH R&D for particle identification (PID) at EIC

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1 Introduction

The design goal of a modular and compact RICH (mRICH) detector is to meet the EIC physics requirements for K/π separation in momentum range from 2 to 8 GeV/c and the physical constraints of the EIC experiments. It also provides excellent e/π separation for momentum up to 2 GeV/c.

The novel design of mRICH consists of four components. A block of aerogel serves as the Cherenkov radiator. Immediately followed by an acrylic Fresnel lens, which focuses the ring image and acts as a UV filter. A pixelated optical sensor is located in the image plane, and the gap between the lens and the image plane is bounded by four flat mirrors. mRICH has been identified as the baseline PID detector in the electron endcap of EIC detector concept in the EIC Yellow Report.

The working principles of mRICH have been tested and verified at the Fermilab test beam facility. The first mRICH prototype was constructed in 2015 and was successfully tested at Fermilab in 2016. The results from the first beam test have been published in NIM A (2017). An improved mRICH prototype was developed in 2017 with a longer Fresnel focal length ($f = 6''$) and a new holder box made of aluminum plates for the mRICH optical component, as shown in Fig. 1. The second mRICH beam test was performed in 2018 with the new prototype and new photosensors of smaller pixel size (Hamamatsu H13700, 3 mm $\times$ 3 mm) in comparison with the sensors (6 mm $\times$ 6 mm) used in the first test. In June of 2021, the very first beam test of a LAPPD was performed at Fermilab for identifying potential single-photon sensors for mRICH. On October 4, 2021, the third mRICH beam test conducted at JLab Hall D using secondary electron beam was successfully completed. This is the first time that mRICH beam test had a tracking system integrated in the test setup.

The main objectives of this proposal are twofold: (a) continuing mRICH performance characterization and improving mRICH design for realistic installation with maximization of acceptance; and (b) mitigating the risk factors of mRICH.

The member institutions of mRICH team include ANL (Junqi Xie), BNL (Edward Kistenev and Alexander Kieslev), Duke University (Zhiwen Zhao), Georgia State University (Xiaochun He, Murad Sarsour and Deepali Sharma), INFN/Ferarra (Marco Contalbrigo), JLab (Alex Eslinger, Kondo Gnanvo, and Benedikt Zihlmann), University of South Carolina (Yordanka Ilieva), University of Virginia (Kondo Gnanvo), and BIND (Alexander Barnyakov).

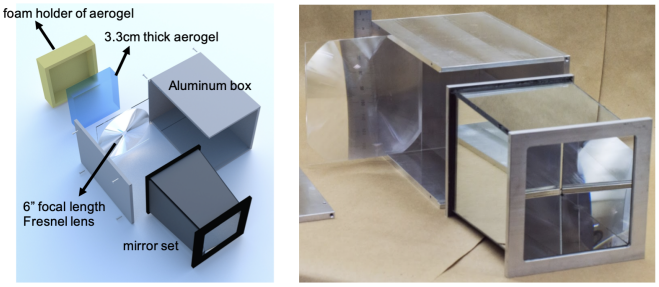

Figure 1: The second mRICH prototype design 3D rendering (left) and the partial detector assembly (right). Optical components only are shown.

2 Proposed mRICH R&D Activities in FY22

The activities we propose for FY22 are very consistent with our plan that was outlined in the eRD14 (PID Consortium) proposal for FY21. In addition, following the active participation in the preparation of EIC detector proposals, mRICH team has identified and prioritized the following R&D tasks for FY22:

- **Data Analysis** This effort includes analyzing the mRICH beam test data at JLab (just completed on October 4, 2021) and finishing up the data analysis from the 2nd mRICH beam test at Fermilab. This task will be led by a postdoc (Deepali Sharma) at GSU with support from Duke (Zhiwen Zhao, Bishnu Karki), INFN (Marco Contalbrigo), JLab (Kondo Gnanvo), and UVA (Xinzhan Bai) groups. *Our milestones are to obtain the single photon angle resolution of mRICH by the end of January 2022 and a paper draft by March 2022.*

- **GEANT4 Simulation** Realistic detector simulation of mRICH has been a vital tool throughout the process of mRICH development. The planned simulation efforts have two components. The first is to fine tune the detector description in GEANT4 to match the mRICH hardware configuration to aid the data analysis both for the JLab test and the Fermilab test. The second effort is to study the mRICH array in the context of EIC detector concept. The goal of the study is to quantify acceptance and efficiency in combination of tracking detectors. This effort will be led by GSU group.

- **mRICH Optical Components** A functioning mRICH includes an aerogel block (a RICH radiator), an acrylic Fresnel lens (for forming a sharper and smaller ring image) and a mirror set (preventing loss of signal photons). Acquiring, characterizing, maintaining aerogel blocks is most challenging for mRICH. This task will be led by INFN group as it was done in eRD14. It should be noted that INFN group also leads the eRD102 R&D and has consolidated experience in using aerogel and mirrors for Cherenkov applications. A synergic R&D on aerogel and mirrors will minimize the overall cost of the project. In parallel, we also want to develop an optical characterization system to measure the lens and mirror properties in order to study and minimize single photon angle resolution. We expect that these efforts could be carried out by GSU students as undergraduate research projects and can be supported from internal sources at GSU. *We plan to complete the construction of the setup by the summer 2022.*

- **Engineering Design** Over the course of eRD14 program, our effort was focused on studying the performance of a single mRICH module (see Fig. 1). It is the time to consider new engineering design of mRICH optical component assembly and the support structure for optimizing the acceptance and system integration. GSU physics machine shop played a key role in machining the components of mRICH prototypes and will continue supporting small scale mechanical design and component fabrication for new prototypes. This will be an in-kind contribution to the mRICH R&D from GSU. We request $20k to support engineers from other institutions to work on the design. Very recently, we started working with an engineer (Alex Eslinger) from JLab, an expert on Aerogel production

Table 1: List of major budget request in FY22.

Category	**Qty**	**Cost**
Postdoc at GSU	1	\$60k
Postdoc at INFN	1	\$40k
Engineering support	2-month	\$20k
Aerogel purchase	10	\$10k
Readout	8	\$20k
Mirrors and Fresnel lens	4 sets	\$2k
GEM tracker and readout	1	\$15k
Material supplies		\$3k

from Russian (Alexander Barnyakov), and Edward Kistenev at BNL to develop a realistic design concept for mRICH. *Our plan is to finalize the design by the end of Spring 2022.*

- **New mRICH Prototype** Preparation for an mRICH performance test, K/π and e/π separation, at Fermilab with tracking capability in F23. We expect to construct a new mRICH prototype by the end of FY22 and to build a complete test setup at GSU including a data acquisition system and a pair of GEM tracker chambers to be purchased from CERN. This setup could serve either as a permanent development station using cosmic rays or a ready-to-go setup for beam tests. In collaboration with the INFN group, an independent readout of the reference H13700 sensors should be realized to avoid scheduling conflicts like the one in 2021 due to electronics sharing with dRICH. Kondo Gnanvo (starting a new position at JLab in November of 2021) will help with the GEM chamber assembly for mRICH.

The estimated funding requests for FY22 are listed in Table 1.

3 Proposed mRICH R&D Activities in FY23/24

The identified R&D activities in FY23/24 will follow the success of the FY22 plans. We will be focusing on realistic beam tests with newly identified photosensors and readout. The general plan includes the following:

- mRICH performance tests (K/π and e/π separation) in FY23 with optimized aerogel and prototype layout.
- mRICH tests with new photosensors in FY24. The expected focus will be using new generation of LAPPD (10cm $\times$ 10cm formfactor) and SiPM sensors with properly engineered cooling.

As it was done in past, the success of mRICH development will depend on team effort with synergies among the members from participating institutions and beyond. It is our intention to closely follow the development in eRD110 and to coordinate joint mRICH beam test. As an example, Kondo Gnanvo from UVA has expressed strong interest in studying LAPPD for mRICH using capacitive pad's readout.

Our projected funding requests include support for purchasing photosensors, readout electronics, travel, and manpower is \$150k per year in FY23 and FY24.